BEYOND EINSTEIN: From the Big Bang to Black Holes

Constellation X

The Constellation X-Ray Mission

Rapporteur Report

Presented by

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NASA

Outline

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  - **"*Gestalt*" – How this meeting felt**
  - **SEP Presentations**
    - **Making up for the RGS removal: Low energy resolution/effective area restoration**
    - **Making up for the HXT removal: High energy effective area restoration**
    - **Other enhancements: Field of view, polarization, mirror coatings**
  - **Technical Presentations: Mirror status, Observatory design for Atlas V**
  - **Science Presentations:**
    - **Black Holes & Gravity: Reynolds et al**
    - **Dark Energy & X-ray Clusters: Allen et al**
    - **WHIM: Bregman et al**
    - **Supernova Remnants & Neutron Stars: Hughes et al**
- **BEPAC Questions: Rapporteur philosophy/desiderata**
  - ***Charge to FST: What should we carry as the Low Energy R / Eff. Area requirement?***
    - ***What should we carry as the High Energy Eff. Area / R requirement?***
    - ***What should we carry as the Field of View requirement?***
  - ***Descope options in case of overruns***

Meeting Summary - *Gestalt*

"*Gestalt*" – n., a configuration or pattern of elements so unified as a whole that it cannot be described merely as a sum of its parts

How this meeting felt

Chumbawamba (1997) – "*Tubthumping*" – *Because we thought it mattered …*

We heard technical progress toward a sound state of readiness for a descoped mission

The SEP submissions can restore much of the critical requirements

The science cases are refined and sharpened toward a BEPAC analysis

The BEPAC process is a concrete milestone to focus our attention

But

There is no funding for support of technical developments from the Con-X project

The BEPAC review has a strong suite of competing proposals

Bottom line

Unless this room believes and can demonstrate that Con-X is the best use of NASA's very limited space astrophysics budget, there will be no new start for a long time

SEP Presentations

Making up for the RGS removal: Low energy resolution/effective area restoration

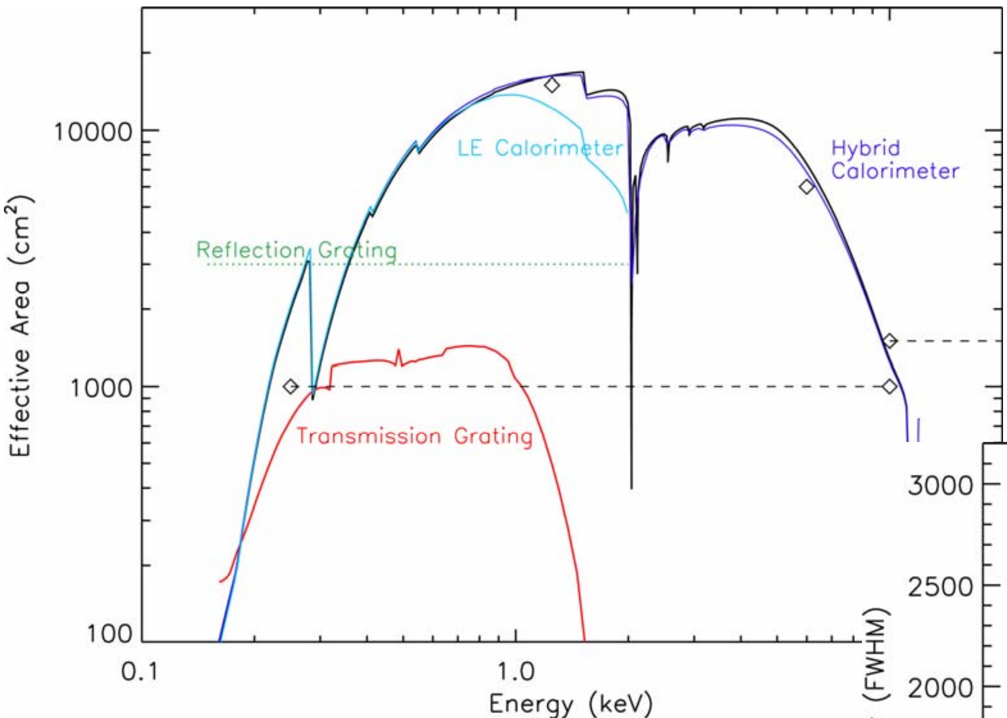
Diffraction Gratings

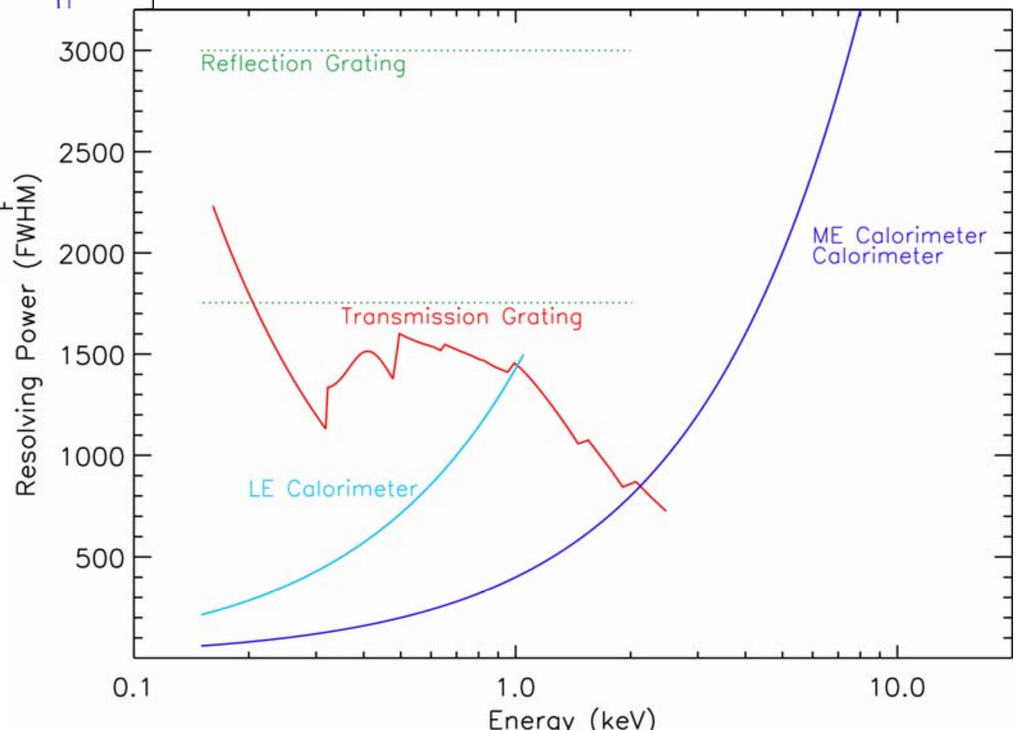
- Movable off-plane reflection grating array located at 1/3L – Lillie, Cash
- Stationary transmission grating arrays – Flanagan

Optimized Calorimeters

- Hybrid mid energy/low energy calorimeter array - Kelley
- Dedicated low energy arrays - Kelley

Low Energy SEP Estimated Performance



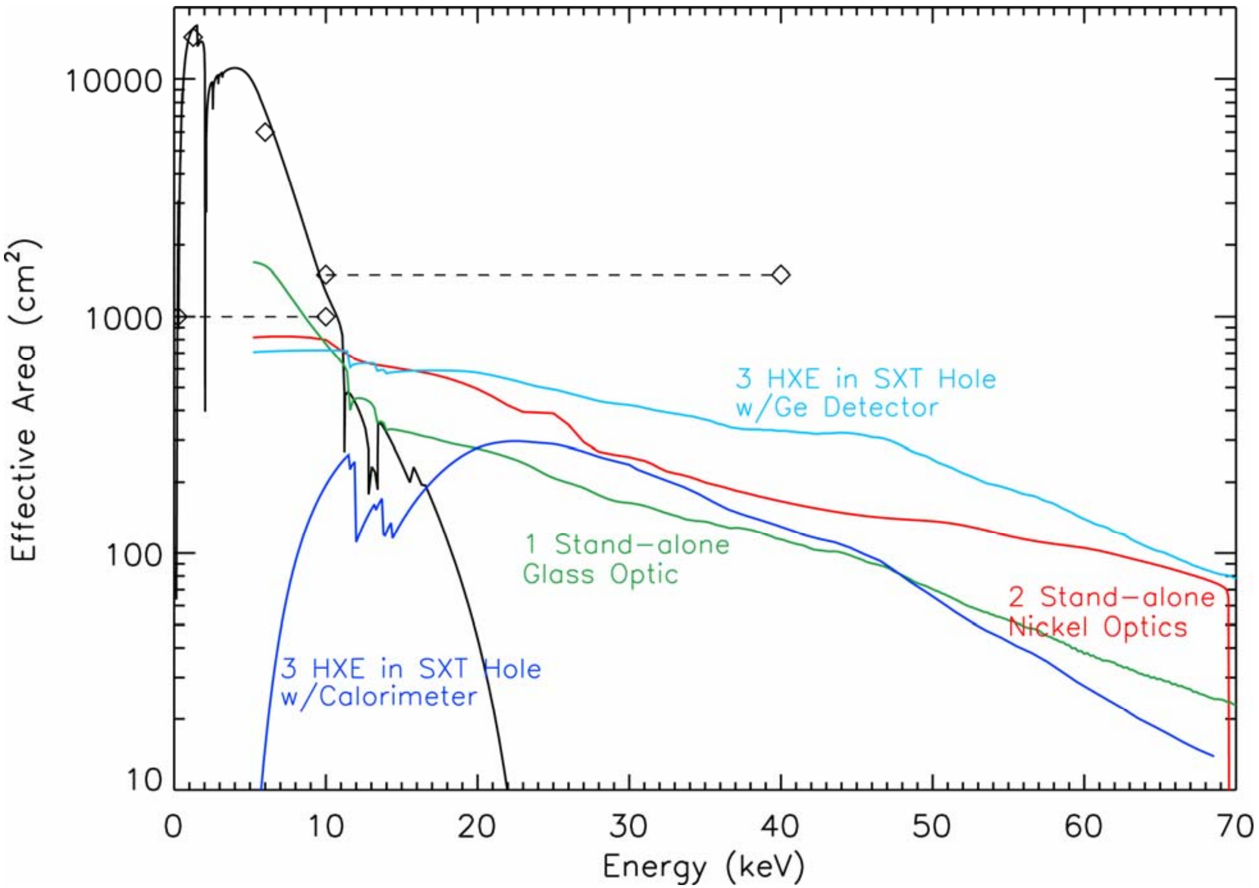


SEP Presentations

Making up for the HXT removal: High energy effective area restoration

- **Stand-alone hard x-ray telescope**
- **Hard x-ray optic implemented at center of SXT with optimized high-energy calorimeters or Ge detectors**
- **Add multilayer coatings to SXT optics with optimized high-energy calorimeters**

High Energy SEP Estimated Performance

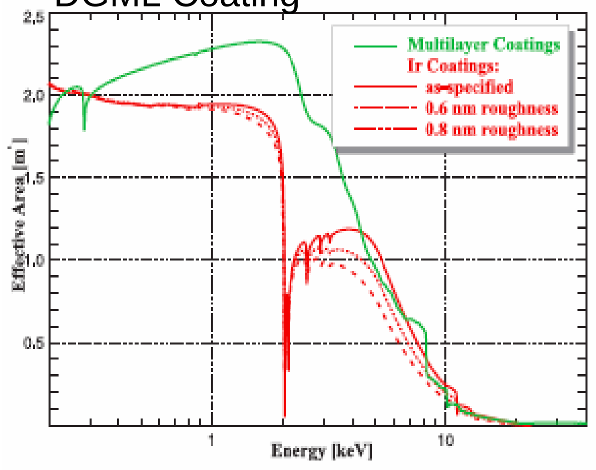


$\Delta E \sim 1$keV for CdZnTe Detectors

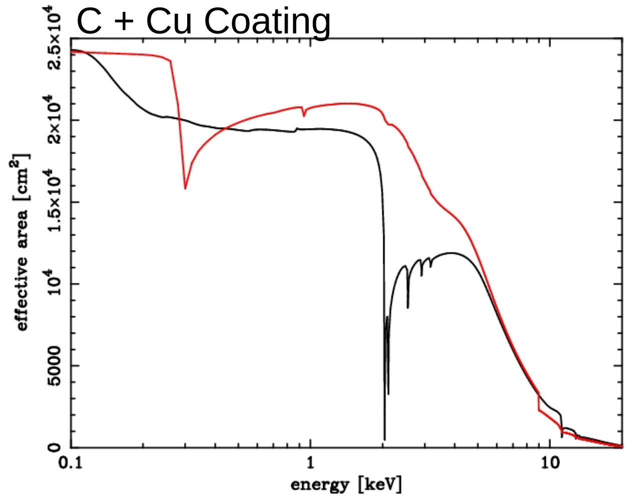
$\Delta E \sim 30$ eV for HE Calorimeters

SXT FMA Coating

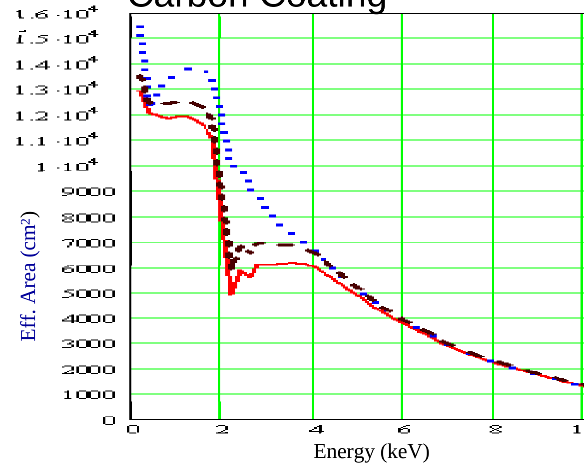
DGML Coating

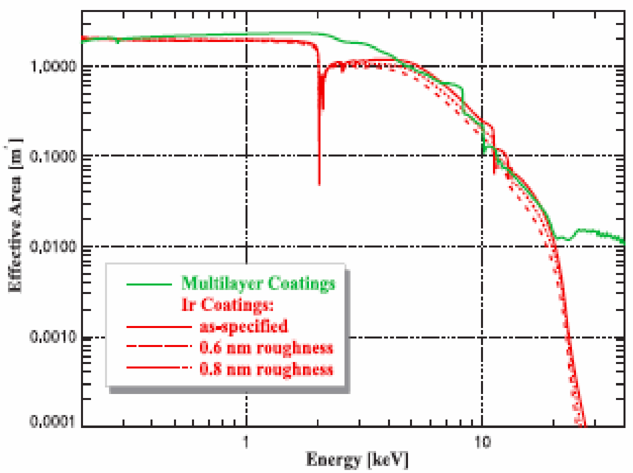


C + Cu Coating



Carbon Coating





- Multilayered SXT provides additional throughput at high energy that could be coupled with a high energy optimized calorimeter.
- All proposed SXT coating concepts, even a simple Carbon layer, provide additional throughput between 1 and 4 keV.

SEP Presentations

Other enhancements: Field of view, polarization, mirror coatings

- **Field of view enhancement**
  - **Add larger pixels with lower energy resolution to cover 10’ x 10’ FoV**
- **Polarimeter**
  - **Measure polarization of X-ray fluxes**
- **Low z coating on SXT mirror shells**
  - **To enhance effective area below 8 keV**

Technical Presentations

- Mirror status
  - While requirements have not yet been met, current status is very close to success
  - Rate of improvement suggests that mirrors can meet requirements by time of selection
- Observatory design for Atlas V
  - Change to single launcher has fit into all parameters of envelope
  - Acceptable margins on all quantities, except perhaps mass
- Baseline calorimeter performance
  - 2.5 eV response on baseline detector arrays seems achievable over 2.5'x2.5' FoV

Science Presentations

Black Holes & Gravity: Reynolds et al

The second energy source in astrophysics: Gravity/Accretion (or is it 1st?)

1. Probe the Kerr metric in strong gravity limit

2. Is rotational energy is extracted from a BH to power an AGN?

measure spectrum as a function of time
measures spin (a), r, i, Mbh
need enough S/N to follow a local peak in the spectrum as it changes in E, intensity

Observational path is clear for 1. but less clear for 2

look for correlation os spin+Mdot with jet power
linkage to blobs spiraling in?

Quantitative goals and comparison with current values

current observations from Chandra, XMM, Suzaku, … (can't do time-resolved obs)
binary pulsars
Gravity Probe-B

Requirements

baseline collecting area and spectral resolution ok

need high energy response to 40 keV (few hundred sq cm)

Science Presentations

Dark Energy & X-ray Clusters: Allen, Vikhlinin et al

Measure $f_{gas}(z)$ and N(M,z)

Some model corrections, then you get to w, w_a (clear path from data to results)

What do you learn from this – don't ask, don't tell

Worries (to me) are being resolved

- accuracy of masses very good (determined from scatter in observations)
- simulations agree with the inferred accuracy (needs to become "common" knowledge)

Must we measure to R_{2500} or is R_{500} good enough?

- difference between 10' fov vs 5' fov
- simulations can guide us here, once calculated

Requirements

- 5' fov with a goal of 10' fov; baseline area is ok
- is the background low enough (to go to R_{500} quickly)?

Once cluster targets known (a few years), Chandra can do the short observations to show if there are bright point sources that could cause problems.

Science Presentations

WHIM: Bregman et al

Measure OVII, OVIII, Ne, Mg in bright AGN continua

Determine dN(OVII)dz, dN(OVIII)/dz at low z: leads to Ω_{baryon} for T = 0.5-5×10^6 K

Requirements

resolution R = 2500 at 0.3-0.7 keV

area of 1000 cm^2

Science Presentations

Supernova Remnants & Neutron Stars: Hughes et al

BEPAC Questions

Rapporteur philosophy/desiderata (Joel)

Risk reduction/ robust design philosophy for maximum life

- Redundancy is good and critical to design

Build/design to fit cost & schedule

Set design requirements & goals with potential for graceful descope if required

Also: don’t forget the value of serendipitous science – we should not reduce the volume of discovery phase space unless there are concrete reasons to do so

BEPAC Questions: Charge to FST

What should we carry as the Low Energy R / Eff. Area requirement?

R > 2500 with >1000 cm^2 from 250 to 1400 eV – requirement

R > 5000 with >3000 cm^2 from 250 to 1400 eV – goal

Principal science driver: WHIM studies – detect lines of O VII, VIII & Mg

What should we carry as the High Energy Eff. Area / R requirement?

>150 cm^2 from 10 to 40 keV with R > 10 – requirement

>600 cm^2 from 10 to 70 keV with R > 10 – goal

Principal science driver: Gravity testing from black hole accretion

What should we carry as the Field of View requirement?

5'x5' (square) with full energy resolution – requirement

10'x10' (square), accepting some energy resolution loss outside 5x5 – goal

Principal science driver: Dark energy studies from X-ray clusters

What angular resolution is required?

15" (required), but 5" is important goal (at least in field center)

And any improvement over 15" is very desireable

What other parameters need analysis as to requirement level?

We heard reasons to assess detector background levels, and observation overheads

BEPAC Questions: Descope options

Descope options in case of overruns

- Drop advanced coatings
- Reduce field of view to 2.5'x2.5'
- Reduce performance requirements on one or two telescope detector systems
- Drop enhancement package on one or two telescopes
    - i.e. drop grating, HE detector, LE array, etc.

Harvey Questions: Energy Resolution Parameterization

How should we state energy resolution requirement?

FWHM? Half Encircled Power? ΔE? Δλ?

Answer: it depends

Qualification – it depends on what question you are asking

Explanation – in general we want to determine:

1. Existence – i.e. does a source or line exist?
2. Location – i.e. what is the position of the source or central E or λ?
3. Amplitude – i.e. what is the brightness of the source or line?

In general real Energy Resolution Kernels are composed of substructure resembling:

1. Sharp – for example, delta function or sharp central peak
2. Broad – for example, Gaussian core of ERK
3. Wide – for example, Lorenzian wings or shoulders on ERK

The problem is that the wide (and sometimes broad) components disappear into the background

Thus for existence or location we may be better off with just the sharp or sharp+broad

(if we derate the effective area) and FWHM is a good measure

Note location improves as $n^{0.5}$ for Broad, location= size of Sharp for n>= 3

For amplitude Half Power is better (if we derate by 2) because it includes power in Wide

Harvey Questions: Energy Resolution Parameterization

How should we state energy resolution requirement?

- *FWHM? Half Encircled Power? ΔE? Δλ?*

So – what do now?

Now pick FWHM or HEP based on analysis of key science projects

- I believe HEP is better for Clusters & Black Holes, FWHM for WHIM
  - <u>But experts should assess this (and we should use derated eff. area for feasibility)</u>

For true Science Requirements Document we should analyze using a real ERF for the real science problem required by